Genet Resour Crop Evol (2012) 59:655–681
DOI 10.1007/s10722-011-9709-2

RESEARCH ARTICLE

Inventory of related wild species of priority crops in Venezuela

Chiara Berlingeri · Manuel B. Crespo

Received: 17 December 2010 / Accepted: 16 May 2011 / Published online: 15 June 2011

Abstract A prerequisite in any conservation programme of Plant Genetic Resources is estimation of diversity. The inventory of wild and naturalized relatives of priority crops in Venezuela (CWR) is based on the main Catalogues of Flora in the country, selecting taxa closely related to crops, according to the concepts of "gene pool" and "taxonomic group". We included 47 genera, 217 species and 228 taxa belonging to 28 plant families. Among them, those with higher richness are: Fabaceae, Solanaceae, Araceae, Lauraceae, Dioscoreaceae, Poaceae, Rosaceae and Myrtaceae. Genera with a higher number of species are *Xanthosoma, Persea, Dioscorea, Prunus, Psidium, Phaseolus, Solanum, Vigna, Capsicum, Manihot, Theobroma, Ipomoea* and *Oryza*. A total of 26 endemic species are found, which belong to genera *Xanthosoma, Persea, Dioscorea, Prunus* and *Manihot*. The primary gene pool of crops include native species from genera such as *Manihot, Solanum* (Section *Petota*), *Lycopersicon, Ananas, Capsicum, Dioscorea, Xanthosoma, Phaseolus, Theobroma, Ipomoea, Gossypium*, *Arracacia* and *Psidium*. Genera with native species weakly related to crops are *Saccharum, Persea, Ipomoea, Prunus, Vigna, Solanum* (Section *Melongena*) and *Daucus*. Crop genera without native species in Venezuela are *Allium, Musa, Brassica, Spinacia, Helianthus, Pisum, Lactuca, Citrus, Elaeis, Beta, Glycine* and *Triticum*. Only a few taxa have already been evaluated according to the IUCN criteria, and Venezuelan accessions of crop wild relatives in national and international genebanks are very scarce.

Keywords Crop wild relatives · Inventory · Plant genetic resources · Venezuela

C. Berlingeri (✉) · M. B. Crespo
CIBIO (Instituto de la Biodiversidad), Universidad de Alicante, P.O. Box 99, 03080 Alicante, Spain
e-mail: cabg1@alu.ua.es; cberlingeri@gmail.com

C. Berlingeri
Instituto Nacional de Investigaciones Agrícolas (INIA), Estación Experimental Trujillo, Avenida Principal de Pampanito, 3152 Estado Trujillo, Venezuela

Introduction

Venezuela shows a higher biological diversity among the Caribbean countries of South America due to the convergence of several biogeographic regions together with a tropical climate, which places it among the top most biodiverse countries worldwide (Huber et al. 1998). Plant diversity with real or potential value for agriculture is known as Plant Genetic Resources (hereafter PGR) and in a broad sense it includes traditional varieties, modern cultivars and Crop Wild Relatives (hereafter CWR; FAO 1996a, 2001). Those resources are basic for the improvement of cultivated plants and agricultural ecosystems sustainability.

In the same way, as the rest of biodiversity, PGR are threatened by mismanagement of landscape. Habitat fragmentation, climate change and agricultural intensification put at risk the crop wild relatives and traditional varieties. Accordingly it is urgent to take actions to reduce genetic erosion. A prerequisite to define strategies for conservation and sustainable use of crop genetic resources is to generate an inventory of CWR to assess the diversity and to keep track of it (FAO 1996b).

The study of PGR can be considered at different scales. In a global perspective, it seems that the number of crops to meet food requirements is relatively small (staple crops), whereas in a local analysis the number of useful plants may increase, becoming then important the underutilized crops, local varieties and wild useful plants. In this frame, the present study was aimed at creating a national inventory of wild and naturalized relatives of priority crops in Venezuela, as a useful tool for the establishment of PGR conservation strategies.

Methods

The inventory of CWR was mainly based on the New Catalogue of the Vascular Flora of Venezuela (Hokche et al. 2008). Taxa recorded there were selected according to its closeness to priority crops of Venezuela, following the "gene pool" concept of Harlan and de Wet (1971) and the "taxonomic group" concept of Maxted et al. (2006). Both native and introduced taxa were included in order to bring a true vision about the importance that these PGR represent in the national economy. Authorships of the names of taxa correspond to those accepted in the International Plant Names Index (IPNI 2011).

The "gene pool" concept takes into account the genetic distance and hybridization ability between the crop and the relatives to assign the latter to a primary (GP1), secondary (GP2) or tertiary (GP3) gene pool of the crop (Harlan and de Wet 1971).

In those cases where information on genetic diversity and hybridization was insufficient, the taxonomic hierarchy was used to estimate the relationship degree. "Taxon groups" were defined according to taxa pertainance to either the same species, series (or section), subgenus, genus or tribe as the crop (TG1, TG2, TG3, TG4 and TG5, respectively) (see Maxted et al. 2006).

Finally, in cases of crop genera in which no formal taxonomic treatments are available (i.e. those in which series, sections or subgenera have not been defined), all species of the concerned genus occurring in Venezuela are mentioned as a potential crop gene pool.

Records in Venezuela for each genus included in the CWR inventory were taken from databases of major herbaria and genebanks worldwide, which were accessed on line through the Global Biodiversity Information Facility, GBIF (www.gbif.net). In those cases in which doubtful records were found, original providers of databases and taxonomists were contacted.

Since the Venezuelan flora is not yet accessible in a database that can be matched digitally with the existing crop databases, the process to produce the national CWR inventory may be carried out manually (Maxted pers. comm. 2008). Therefore, a list of priority crops in Venezuela was first established by consulting national and international statistics. Secondly, it was compared with the taxonomic treatments and genetic diversity studies of genera to select those taxa belonging to the corresponding "gene pool" or "taxonomic group" of the priority crops.

Once the list of species was completed, the database was supplemented with additional information to facilitate the selection of taxa requiring further research or conservation actions. Table 1 shows criteria followed here to generate the CWR datable in Venezuela, which is mostly based on those used by previous authors to priorize species for conservation (Maxted et al. 1997; Magos 2008).

Results and discussion

Taxonomic diversity of crop wild relatives

The inventory of priority CWR for Venezuela ("Appendix") is arranged according to the economic importance of the crop. It includes 47 genera, 217 species and 228 taxa belonging to 28 plant families. Of these, those with higher taxa richness are Fabaceae, Solanaceae, Araceae, Lauraceae, Dioscoreaceae, Poaceae, Rosaceae and Myrtaceae, which comprise 67% of the whole taxa included in the inventory. The families with most genera with native species are Solanaceae and Fabaceae (Table 2).

Table 1 Criteria considered for the database elaboration of CWR in Venezuela

Criteria	Categories	Sources of information
Scientific name	–	Hokche et al. (2008)
		IPNI, The International Plant Names Index. Published on the Internet http://www.ipni.org (accessed May 2011)
Synonyms	–	Hokche et al. (2008).
		TROPICOS (2009), Missouri Botanical Garden, http://www.tropicos.org (accessed January 2009)
Status	Endemic, native, naturalized, introduced (archaeophyte, neophyte), Uncertain.	Hokche et al. (2008)
		Harlan (1992)
		Mabberley (2008)
Economic importance	Production value of the related crop in Venezuela	FAO (2005) FAOSTAT, http://faostat.fao.org (accessed September 2008)
Taxonomic relationship with the crop	TG1a, TG1b, TG2, TG3, TG4 and TG5.	Accepted taxonomic treatments for the genus (see "Appendix" for references)
		USDA, ARS, Germplasm Resourses Information Network (GRIN), http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl (accessed February to July 2009)
Genetic relationship with the crop	GP1a, GP1b, GP2, GP3	See "Appendix" for references
Threat degree	Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR),	The IUCN Red List of Threatened Species (2009), http://www.iucnredlist.org (accessed April 2009)
		Llamozas et al. (2003)
Distribution	Pantropical, paleotropical, neotropical, Endemic.	Mabberley (2008)
		Hokche et al. (2008)
		TROPICOS (2009), Missouri Botanical Garden, http://www.tropicos.org (accessed April 2009)
National and International *ex situ* conservation	Number of collections and accessions in national and international genebanks	GBIF, Global Biodiversity Information Facility (2009), http://www.gbif.net (accessed June 2009)
		Bioversity International (2009), http://www.bioversityinternational.org (accessed June 2009)
		SINGER, The System—wide Information Network for Genetic Resources (2009), http://www.singer.cgiar.org/index.jsp?page=collections
		Knudsen (2000)

Only 24 (51%) out of 47 genera related with priority crops have native species in Venezuela, while 23 (49%) are introduced. As regards to the taxa listed, 140 are native, 55 are introduced and 33 have a doubtful origin (Table 2). Among the introduced species, both archaeophytes (12) and neophytes (44) can be found. The former are species whose introduction was long before the discovery of America, so it is likely that evolutionary adaptations have occurred during all that time. The neophytes are plants introduced after the American discovery, so they probably have a narrower diversity. However, no generalization is possible, because this issue has much to do with the reproduction way and biology of each species.

The taxonomic representation of the genera was estimated by the ratio between the number of Venezuelan species and the total number of species known for each genus, following Mabberley (2008). According to that, the genera of cultivated plants best represented in Venezuela are *Capsicum*, *Ananas, Xanthosoma, Theobroma, Cucurbita, Oryza, Zea*, *Psidium*, and *Phaseolus*.

Table 2 Summary of taxa diversity of major crop relatives in Venezuela

Crop	Family	Genus	Species number	Taxa number	Endemic	Native	Archaeophyte	Neophyte	Doubtful
Corn	Poaceae	*Zea*	1	2			1		1
Rice	Poaceae	*Oryza*	6	6				2	4
Sugarcane	Poaceae	*Saccharum*	4	4				1	3
Cassava	Euphorbiaceae	*Manihot*	7	8	1	7			
Plantain, Banana	Musaceae	*Musa*	1	2				2	
Potato	Solanaceae	*Solanum*	9	10		8			2
Pineapple	Bromeliaceae	*Ananas*	4	4		1	2		1
Onion, Garlic	Alliaceae	*Allium*	2	2				2	
Coffee	Rubiaceae	*Coffea*	3	3				3	
Sorghum	Poaceae	*Sorghum*	4	4				4	
Tomato	Solanaceae	*Lycopersicon*	1	2		1			1
Melon, Cucumber	Cucurbitaceae	*Cucumis*	5	5				4	1
Peppers	Solanaceae	*Capsicum*	8	10		5			5
Carrot	Apiaceae	*Daucus*	2	2		1		1	
Coconut	Arecaceae	*Cocos*	1	1					1
Watermelon	Cucurbitaceae	*Citrullus*	1	1				1	
Orange, other citruses	Rutaceae	*Citrus*	4	4				4	
Papaya	Caricaceae	*Carica*	1	1			1		
Tobacco	Solanaceae	*Nicotiana*	2	2		1	1		
Yam	Dioscoreaceae	*Dioscorea*	18	18	5	11		2	
Tannia	Araceae	*Xanthosoma*	22	22	13	9			
Avocado	Lauraceae	*Persea*	20	21	5	15			1
Beans	Fabaceae	*Phaseolus*	10	10		7	1		2
Guava	Myrtaceae	*Psidium*	13	13		12			1
Mango	Anacardiaceae	*Mangifera*	1	1				1	
Cacao	Sterculiaceae	*Theobroma*	7	8		8			
Sesame	Pedaliaceae	*Sesamum*	1	1				1	
Grape	Vitaceae	*Vitis*	2	2				1	1
Cabbage, Cauliflower	Brassicaceae	*Brassica*	1	2				2	
Lettuce	Asteraceae	*Lactuca*	1	1				1	
Cotton	Malvaceae	*Gossypium*	2	2		1	1		
Strawberry	Rosaceae	*Fragaria*	1	1				1	
Peach	Rosaceae	*Prunus*	13	13	2	8		1	2
Beet	Chenopodiaceae	*Beta*	1	1				1	
Sweet potato	Convolvulaceae	*Ipomoea*	6	6		5			1
Eggplant	Solanaceae	*Solanum*	1	1				1	
Pigeon pea	Fabaceae	*Cajanus*	1	1				1	
Sisal	Agavaceae	*Agave*	3	4		3			1
Soya	Fabaceae	*Glycine*	1	1				1	
Peanut	Fabaceae	*Arachis*	3	3		1			2
Sunflower	Asteraceae	*Helianthus*	1	1				1	

Table 2 continued

Crop	Family	Genus	Species number	Taxa number	Endemic	Native	Archaeophyte	Neophyte	Doubtful
Peas	Fabaceae	*Pisum*	1	1				1	
Wheat	Poaceae	*Triticum*	1	1				1	
Cowpea	Fabaceae	*Vigna*	10	10		7		1	2
Pumpkin, Squash	Cucurbitaceae	*Cucurbita*	4	4			4		
Arracacha	Apiaceae	*Arracacia*	4	4		3			1
Palm oil	Arecaceae	*Elaeis*	1	1				1	
Spinach	Chenopodiaceae	*Spinacia*	1	1				1	
Total			217	228	26	114	11	44	33

The inventory of CWR contains 26 endemic species to Venezuela (12%), belonging to genera *Xanthosoma* (13), *Persea* (5), *Dioscorea* (5), *Prunus* (2) and *Manihot* (1) (Table 2). The highest percentage of endemic species is found in Amazonas and Bolívar states, followed in smaller numbers by Lara, Merida and Táchira (Hokche et al. 2008).

Likewise, genera with distributions restricted to the Americas are also important (e.g. such as *Xanthosoma, Psidium, Phaseolus, Capsicum, Manihot, Theobroma, Ananas, Arracacia, Cucurbita, Arachis, Agave, Lycopersicon, Carica, Helianthus* and *Zea*), which account for 90 species (41%). Other infrageneric taxa are also endemic to America, such as *Solanum* sect. *Petota* and the CCDD genome species of *Oryza* (Hawkes 1990; Hijmans and Spooner 2001; Subudhi et al. 2006).

Genera including the highest number of species are *Xanthosoma, Persea, Dioscorea, Prunus, Psidium, Phaseolus, Solanum, Vigna, Capsicum, Manihot, Theobroma, Ipomoea* and *Oryza* (Table 2). This fact responds to the inclusion of species according to the genetic and taxonomic proximity of wild taxa to the crop, since more accurate genetic data were not available.

Diversity assessment of crop genera in Venezuela

According to FAO statistics (FAO 2005) the most commercially valuable crop in Venezuela is maize (*Zea mays* L.). Although Venezuela has no related wild species of this crop, there exists great infraspecific diversity with a high potential for genetic improvement and direct use (Grant et al. 1965; Alfaro and Segovia 2000).

Rice (*Oryza sativa* L.) and sugarcane (*Saccharum officinarum* L.) occupy respectively the second and third position in commercial value. Venezuela is neither the origin centre nor the diversity centre for both species, this showing the dependence of the country for those food genetic resources. In the case of the genus *Saccharum*, although the diversity of native species has not been studied, they are geographically and taxonomically distant from the crop species complex (D'Hont et al. 2008).

The genus *Oryza* is usually classified into 21 wild and two cultivated species, which have been assigned to ten distinct genomes following hybridization studies and molecular analyses (Khush 1997; Subudhi et al. 2006). In Venezuela only three species are found belonging to the *O. sativa* complex with AA genome (*O. sativa* L., *O. rufipogon* Griff. and *O. glumaepatula* Steud.) and three species from the *O. officinalis* complex with CCDD genome (*O. alta* Swallen, *O. grandiglumis* (Döll) Prodoehl and *O. latifolia* Desv.). The species *O. glumaepatula*, *O. alta*, *O. grandiglumis* and *O. latifolia* are endemic to Neotropics (Khush 1997; Subudhi et al. 2006). Although *O. glumaepatula* is not mentioned in floristic catalogues of Venezuela, the website "Cereal Knowledge Bank" managed by the IRRI and CIMMYT (http://www.knowledgebank.irri.org/default.htm) includes Venezuela in the range of distribution for this species. Populations of *O. glumaepatula* show a great variation and are difficult to distinguish morphologically from other species with AA genome

(Juliano et al. 1998), being often referred as a synonym of *O. rufipogon* (www.tropicos.org). However, there are reproductive barriers (Naredo et al. 1998) and molecular differences (Ge et al. 1999) that warrant segregation of *O. glumaepatula* from the Asian AA genome of *O. rufipogon*. Similarly the genetic diversity of CCDD genome species from Latin America is unclear. Molecular and hybridization data show that CCDD species are very closely related and appear to have varied according to ecological conditions (Jena and Kochert 1991). The presence of wild (or feral) rice with AA genome in Venezuela, which continuously are exchanging genes with the crops (Chen et al. 2004), and the scarce knowledge about the genetic identity of AA and CCDD populations makes a priority the phylogeographic study of the genus in Venezuela (Pérez-Almeida pers. comm. 2009).

Manihot, Solanum (section *Petota*), *Ananas, Lycopersicon, Capsicum, Dioscorea, Xanthosoma, Phaseolus, Psidium, Theobroma, Gossypium, Ipomoea* and *Arracacia* are economically the most important genera with native species in Venezuela, which belong to the primary gene pool of the crops. Among them, *Manihot, Solanum, Capsicum, Dioscorea, Xanthosoma, Phaseolus, Psidium, Theobroma* and *Ipomoea*, include over 10 species each (Table 2).

The most recent monograph of *Manihot* classifies *M. esculenta* as the only species within the section *Manihot* (Rogers and Appan 1973). However, phylogenetic studies have shown that sections accepted by Rogers and Appan (1973) are not monophyletic, therefore the genus is now in need of revision (Chacón et al. 2008). Furthermore, although *M. esculenta* belongs to a particular section, it can produce hybrids with some wild species of other sections (Nassar et al. 2008), suggesting that some of those sections may be closer. Since in Venezuela there are wild populations of *M. esculenta* and related wild species, including the endemic species *M. filamentosa* Pittier, it would be interesting to deal with phylogeographic studies of the genus for conservation purposes.

The classification system most widely used for *Solanum* (D'Arcy 1972, 1991) arranges the genus into seven subgenera, including subg. *Potatoe* (G. Don) Walp., to which *S. tuberosum* L. (potato) belongs, and the subgenus *Leptostemonum* (Dunal) Bitter, which includes *S. melongena* (egg-plant). No wild relatives of the latter species are found in Venezuela. The wild relatives of potato are grouped into *Solanum* section *Petota* Dumort subsection *Potatoe*, according to the classification of Hawkes (1990), being very frequent the interspecific hybridization within subsection (Spooner and Hijmans 2001). In the Catalogue of the Flora of Venezuela (Hokche et al. 2008) are reported seven wild species of *Solanum*, section *Petota* in the Andean states of Venezuela (*Solanum colombianum* Dunal, *Solanum juglandifolium* Humb. et Bonpl. ex Dunal, *Solanum otites* Dunal, *Solanum paramoense* Bitter ex Pittier, *Solanum subpanduratum* Ochoa, *Solanum tuberosum* L., *Solanum woodsonii* Correll). However, the database of the International Potato Center (CIP) shows a record identified as *S. curtilobum* Juz. et Bukasov collected in Trujillo state, and *S. flahaultii* Bitter is recorded by several authors (Nee 1999; Hawkes 1990; Luteyn 1999) as present in Venezuela. The existence of *S. curtilobum* in Venezuela is not surprising, as it is a cultivated species (Spooner, pers. comm.).

The results of morphological, enzymatic, karyological, hybridization and molecular analyses support the hypothesis that three independent evolutionary lineages are involved in the origin of the domesticated *Capsicum*. *C. annuum, C. chinense and C. frutescens* integrate the "white flowered *C. annuum* group", in which few reproductive barriers and high morphological and molecular similarities exist. A second lineage with yellow-spotted white flowers includes *C. baccatum*, and finally, a third lineage includes the shrubby purple-flowered *Capsicum* to which *C. pubescens* belongs (McLeod et al. 1982; Walsh and Hoot 2001; Moscone et al. 2006). In terms of hybridization ability, the species of *C. pubescens* complex are fully compatible to one another, but show unilateral incompatibility with species from other groups. Crosses between species of the remaining two groups show no incompatibility (Naci and Pickersgill 2004). Relationships of *C. cumanense* Fingerh. and *C. rhomboideum* Kuntze with the rest of Venezuelan *Capsicum* species and their taxonomic status, are rather uncertain due to the absence of studies.

Although the Catalogue of the Flora of Venezuela (Hokche et al. 2008) does not include *C. chinense*, the database of the National Plant Germplasm System of the United States Department of Agriculture, (USDA—ARS) (http://sun.ars-grin.gov/npgs/searchgrin.html) and the Centre for Genetic Resources at Wageningen University, CGN (http://www.cgn.wur.

nl/applications/cgngenis/) registered accessions collected in Venezuela.

Cultivated taxa of *Dioscorea* appear to have been originated in tropical regions of three continents. Among these, *D. trifida* L.f is the only cultivated species originated in South America (Mignouna et al. 2007), and also it is the only Venezuelan species included by Knuth (1924) in the section *Macrogynodium* (subgenus *Eudioscorea*). Knuth's classification divides the genus into four subgenera and 58 sections, but recent phylogenetic studies have provided evidence for the reclassification of Dioscoreaceae and its genera (Caddick et al. 2002), as well as for simplifying the classification proposed by Knuth (Wilkin et al. 2005).

Engler (1920) arranged the genus *Xanthosoma* in two sections: *Euxanthosoma* and *Acontias*. After that, many species have been reported for Venezuela (Bunting 1975, 1979, 1986, 1988; Madison 1981; Croat and Lambert 1986), though only describing the morphology and distribution of the species. There is not an updated taxonomic treatment of the genus or references about phylogenetic relationships among species. In the present inventory, therefore, all species of *Xanthosoma* reported for Venezuela are included.

With regard to *Phaseolus*, the Catalogue of the Vascular Flora of Venezuela (Hokche et al. 2008) includes eight species; however three of these were transferred to the related genera *Macroptilium* and *Vigna* according to a narrower circumscription of the genus. Also, *P. aborigineus* Burkart is regarded as *Phaseolus vulgaris* L. var. *aborigineus* (Burkart) Baudet. The presence of *P. tuerckheimii* in Venezuela is cited for the states of Monagas and Táchira, although Delgado-Salinas et al. (2006) restricted its range only to Mexico and Central America. Likewise, *P. unilobatus* was published as a new species by Pittier (1944) from a single sample collected in the Monagas state, this species being only accepted in the Venezuelan catalogue (Hokche et al. 2008). Moreover, the database of the USDA-ARS (http://sun.ars-grin.gov/npgs/searchgrin.html) includes an accession labelled *P. dumosus* Macfad, collected in Mérida, Venezuela. This species is referred as native to Central America but it is cultivated and widely naturalized in northwestern South America. In addition, in the Nationaal Herbarium Nederland (NHN) and the Missouri Botanical Garden (MO) there are samples identified as *P. coccineus* subsp. *darwinianus* collected in Venezuela. Since the taxonomic definition and nomenclature of the Venezuelan species of *Phaseolus* is uncertain and confusing, there is a need for a revision of the genus for the country. We are currently undertaking a revision to define key characters for taxa identification, to establish their geographical distribution and to infer their phylogenetic relationships.

The sweet potato (*Ipomoea batatas* (L.) Lam.) and its closest wild relatives belong to subgenus *Eriospermum* Verdc., section *Eriospermum* Hallier f., series *Batatas* (Choisy) D.F. Austin (Austin and Huáman 1996). Crossing of species within this group is complex because of genetic, cytogenetic and physiological interactions. Studies with molecular markers and cytogenetics have been used to infer phylogenetic relationships in the group, confirming a close relationship between *I. batatas* and *I. trifida* G.Don and a greater genetic distance with the rest of species in the series (Huang et al. 2002; Rajapakse et al. 2004; Srisuwan et al. 2006).

Threat degree of taxa

Estimating the threat degree of native taxa related to cultivated species is very difficult in Venezuela, due to the lack of detailed studies on that subject. In the present work the list of endangered species of IUCN (www.iucnredlist.org) and the Red Book of Venezuela (Llamozas et al. 2003) were checked. The latter assigned threat categories to 1,598 out of 15,820 native species reported in the Catalogue of Venezuela (Hokche et al. 2008). Table 3 shows the crop relatives included in any of the IUCN categories. Only seven species in the present inventory have been evaluated, which are in the lower risk categories. The scarce number of taxa so far evaluated under the IUCN criteria as well as the poor knowledge about conservation status of populations of crop relatives, highlight the urgent need to conduct such studies.

Another approach useful to estimate the threat of taxa is to consider their geographic distribution and endemicity. This information was taken from the New Catalogue of the Vascular Flora of Venezuela (Hokche et al. 2008), in which the distributions were based on data from the herbarium specimens and literature. Since some areas of the country have not been adequately sampled yet and many taxa are

Table 3 Crop relatives included in lists of threatened species

Family	Taxon	Status	IUCN category
Euphorbiaceae	*Manihot brachyloba* Müll.Arg.	Native	MR/pm
Euphorbiaceae	*Manihot filamentosa* Pittier	Endemic	IC
Euphorbiaceae	*Manihot surinamensis* D.J. Rogers et Appan	Native	MR/pm
Euphorbiaceae	*Manihot tristis* Müll.Arg. subsp. *tristis*	Native	IC
Lauraceae	*Persea caerulea* (Ruiz et Pav.) Mez	Native	MR/pm
Myrtaceae	*Psidium cinereum* DC.	Native	MR/ca
Solanaceae	*Solanum flahaultii* Bitter	Doubtful	MR

scarcely collected in the herbaria, the present analysis must be considered preliminary in order to select priority taxa for future studies.

As mentioned before, endemic species related to crops belong to *Xanthosoma, Persea, Dioscorea, Prunus* and *Manihot*. Llamozas et al. (2003) cited *Solanum paramoense* and *S. subpanduratum* as endemic to the Venezuelan Andes. However, several authors consider *S. subpanduratum* as a synonym of *S. colombianum*, and others doubt about the status of *S. paramoense* which is a matter of current work (Spooner, pers. comm.).

Most endemic species are distributed in the south of Orinoco River (Bolivar and Amazonas states), excepting *Xanthosoma, Manihot* and *Solanum* that have endemic species towards the north of Venezuela. In this regard, it is noteworthy that the states located in the south of Venezuela have a population density and habitat fragmentation considerably smaller than those in the north, and therefore the degree of threat to those populations is very likely weaker.

When the genera with native species are considered, the highest species richness is concentrated in Guayana and Andes regions. *Dioscorea, Theobroma* and *Ananas* have the highest species representation in the southern parts of the country (Amazonas and Bolivar states). The genus *Arracacia*, *Solanum* (section *Petota*) and *Phaseolus vulgaris* var. *aborigineus* (the closest wild relative of beans) are concentrated in the Andean states. Some genera have a wide distribution in the country, such as *Xanthosoma*, *Manihot* and *Capsicum*.

Conservation status of taxa

Only 44 taxa (19%) out of those included in the present inventory have at least one entry in international genebanks. Of these, 25 are cultivated species (57%) and 19 are wild ones (43%). Regarding to *ex situ* conservation in Venezuela, 37 taxa (16%) are present in national genebanks, most of which correspond to cultivated species (32 taxa, 86%). Only five taxa (14%) belong to non cultivated species: *Lycopersicon esculentum* var. *cerasiforme* (Dunal) A.Gray, *Solanum tuberosum* subsp. *andigenum*, *Theobroma grandiflorum* (Willd. ex Spreng.) K.Schum., *Ananas parguazensis* Camargo et L.B.Sm. and *Ananas nanus* (L.B.Sm.) L.B.Sm. ("Appendix"). This suggests a low representation of Venezuelan plant genetic resources in national and international genebanks, especially of wild relatives of crops. However, the above must be analyzed carefully, since many genebanks, mainly those of Venezuela, lack updated online database and there are still many materials not fully identified (Pérez pers. comm. 2009).

The genera with greater representation of taxa collected in Venezuela conserved in international genebanks are *Lycopersicon* (2), *Gossypium* (2), *Nicotiana* (2), *Vigna* (7), *Solanum* (6), *Zea* (1), *Phaseolus* (5), *Capsicum* (5) and *Ipomoea* (3). The species with the highest number of Venezuelan accessions in international genebanks are *Zea mays, Phaseolus vulgaris, Manihot esculenta, Sorghum bicolor, Gossypium hirsutum, Sesamum orientale, Cajanus cajan* and *Ipomoea batatas*.

Genera with a higher number of taxa included in national collections are probably *Ananas*, *Zea* and *Gossypium*. The species with the highest number of accessions in national genebanks are *Zea mays, Phaseolus vulgaris, Oryza sativa, Theobroma cacao, Manihot esculenta, Sorghum bicolor, Sesamum orientale, Vigna unguiculata, Cocos nucifera, Mangifera indica, Ipomoea batatas, Cajanus cajan,* and those of *Coffea*, *Lycopersicon*, *Gossypium* and *Capsicum*.

No or very few Venezuelan germplasm of cultivated and related wild species of *Dioscorea, Xanthosoma, Arracacia, Agave, Cucurbita* and *Carica* have been collected, despite the regional or local importance of those crops. No *ex situ* germplasm accessions exist of endemic Venezuelan crop relatives of *Xanthosoma, Persea, Dioscorea, Prunus* and *Manihot* ("Appendix").

Estimating the risk of gene escape from genetically modified organisms (GMOs)

In Venezuela, any activity related to GMOs that involves its release, production, trade and public use is not legally permitted. However, large quantities of seeds and agricultural products are imported from countries where production of transgenic crops is a common practice. In addition, several Venezuelan institutions are conducting genetic engineering projects (Delgado 2005). Consequently, the risk of escape of transgenic genes to nature and the commercial release of GMOs exists in a medium-term. In September 2003 the Cartagena Protocol, which considers the evaluation of the risks associated with transit, handling and use of GMOs for biodiversity conservation, became effective in Venezuela. Also the law of Biological Diversity of Venezuela (Ley de Diversidad Biológica 2000) establishes biosafety measures.

The transgenic gene transfer to native or naturalized species may occur through intraspecific and interspecific hybridization, which would allow the continuation of these genes in nature and likely could affect agricultural activity and biodiversity. Although in the present inventory 58 priority crops were considered, the risk of gene escape varies depending on the crop. In Venezuela wild forms of cultivated species exist, such as *Solanum tuberosum* subsp. *andigena*, *Lycopersicon esculentum* var. *cerasiforme*, *Ananas comosus* var. *parguazensis*, *Capsicum annuum* var. *glabriusculum* and *Phaseolus vulgaris* var. *aborigineus*. All these have high reproductive compatibility with crops, which means that production of fertile hybrids is possible and probable. Other cultivated species natives to Venezuela are cotton (*Gossypium barbadense*), sweet potato (*Ipomoea batatas*), cacao (*Theobroma cacao*), yam (*Dioscorea trifida*), tannia (*Xanthosoma sagittifolium*) and cassava (*Manihot esculenta*).

Special care must also be taken with transgenic crops of introduced species that are regularly found in the natural vegetation and are able to naturalize in the wild, such as corn (*Zea mays*), squashes (*Cucurbita* sp. pl.), tobacco (*Nicotiana tabacum*), avocado (*Persea americana*), sesame (*Sesamum orientale*), cotton (*Gossypium hirsutum*), rice (*Oryza sativa*), coffee (*Coffea* sp. pl.), coconut (*Cocos nucifera*), strawberry (*Fragaria vesca*), guava (*Psidium guajava*), mango (*Manguifera indica*), melon (*Cucumis melo*), cucumber (*Cucumis sativus*), papaya (*Carica papaya*), pigeon pea (*Cajanus cajan*) and watermelon (*Citrullus lanatus*).

On the other hand, it is important to consider those cultivated species capable of exchanging genes with other related species. It is the case fo *Solanum tuberosum* and the rest of species of section *Petota*; *Ipomoea batatas* and the wild species *I. trifida*; *Oryza sativa* and genome AA species (*O. rufipogon* and *O. glumaepatula*); *Capsicum annuum* complex species; annual and perennial taxa of *Sorghum*; cultivated species of *Cucurbita*; and *Vitis vinifera* and the American species *V. tiliifolia*. The experimental hybridization between *Cucumis sativus* and *Cucumis melo* is also possible (Deakin et al. 1971).

At the present, commercial genetic modified crops exist of potato, tomato, cotton, corn, rice, melon, tobacco, squash and papaya, among others (Delgado 2005). Besides, many others transgenic are in progress to be produced, among which bean and pineapple are found. In this regard, especial attention may be payed to erosion risk assessment in these crops.

Another important issue in biodiversity conservation is the estimation of genetic contamination risks for endemic species. In Venezuela, endemic taxa are found in *Xathosoma, Dioscorea, Manihot, Persea* and *Prunus*, but their real relationships with the related crops are unknown. However, tannia (*Xanthosoma sagittifolium*), yam (*Dioscorea trifida*) and cassava (*Manihot esculenta*) are regional important crops, in which no transgenic varieties are known to date. Avocado (*Persea americana*) and peach (*Prunus persica*) are taxonomically distant from the Venezuelan species of those genera, and they are likely to be also genetically distant.

Genera of priority crops without native or naturalized species in Venezuela are *Allium, Musa, Brassica, Spinacia, Helianthus, Pisum, Lactuca, Citrus, Elaeis,*

Beta, Glycine and *Triticum*. The cultivated species *Solanum melongena, Saccharum officinarum, Prunus persica, Vigna unguiculata* and *Daucus carota* seem to be remotely related to the Venezuelan native species, although no specific studies on their crossing ability have been made.

Conclusions

The present work was aimed at creating a national inventory of crop relatives for Venezuela, establishing a list of priority crops, and selecting manually taxa closest to the crops according to their genetic and/or taxonomic relationships. In this regard, a large amount of related literature was reviewed and synthesized in order to generate a list of priority species that can facilitate taxa selection for future studies and activities related to conservation and use of plant diversity. The inventory allows estimating the importance and research needs of taxa according to the following criteria: (1) economic importance of their related crop; (2) their taxonomic richness and representativeness; (3) the presence of endemic and native taxa; (4) the genetic relationships with the crop (their potential as gene donors and genetic pollution risks); (5) extinction risk, and (6) their inclusion in genebanks.

Although a more general perspective could have been developed if a digitalized flora were available, the number of taxa possible to be managed for conservation purposes is limited. Results from CWR inventories in Europe have shown that a high proportion of the wild flora has potential as crop relatives, and in these cases a posterior prioritization process has been recommended (Maxted et al. 2007; Magos et al. 2008). In the present contribution the prioritization criteria were initially established and the practical utility of the methodology was confirmed to select priority taxa for conservation.

The genera with native species that are part of the gene pool of the crop are: *Manihot, Solanum* (Section *Petota*), *Lycopersicon, Ananas, Capsicum, Dioscorea, Xanthosoma, Phaseolus, Theobroma, Ipomoea, Gossypium, Psidium* and *Arracacia*. Further studies are still needed to determine the diversity and relationships between most of the genera and the related crop, though the Venezuelan species of *Saccharum, Persea, Ipomoea, Prunus, Vigna, Solanum* (Section *Melongena*) and *Daucus* seem to be weakly related to crops. The genera of priority crops that probably have no native or naturalized species in Venezuela are *Allium, Musa, Brassica, Spinacia, Helianthus, Pisum, Lactuca, Citrus, Elaeis, Beta, Glycine* and *Triticum*.

The number of taxa that have been evaluated to date according to the IUCN criteria is virtually zero; and a low representation of Venezuelan CWR accessions exist in national and international genebanks. This is particularly true for the major genera *Phaseolus, Capsicum, Ananas, Lycopersicon, Oryza, Manihot* and *Psidium*, and for genera regionally important such as *Dioscorea, Xanthosoma, Arracacia, Agave, Cucurbita* and *Carica*. There are no germplasm in genebanks from Venezuelan endemic species of *Xanthosoma, Persea, Dioscorea, Prunus* and *Manihot*.

Appendix

See Table 4.

Table 4 Inventory of major crop relatives in Venezuela

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
Corn	Poaceae	*Zea*	*Zea mays* L. subsp. *mays*		Archaeophyte	TG1		GP1	X	X	Grant et al. (1965), Alfaro and Segovia (2000).
			Zea mays L. subsp. *mexicana* (Schrad.) H.H.Iltis		Doubtful	TG1		GP1			
Rice	Poaceae	*Oryza*	*Oryza alta* Swallen	*Oryza latifolia* Desv.	Doubtful	TG3		GP3			Khush (1997), Vaughan and Tomooka (1999), Vaughan et al. (2003)
			Oryza glumaepatula Steud.		Doubtful	TG2		GP2	X		
			Oryza grandiglumis (Döll) Prodoehl		Doubtful	TG3		GP3			
			Oryza latifolia Desv.	*Oryza alta* Swallen	Doubtful	TG3		GP3			
			Oryza rufipogon Griff.	*Oryza perennis* Moench	Naturalized	TG2		GP2			
			Oryza sativa L.		Naturalized	TG1		GP1	X	X	
Sugarcane	Poaceae	*Saccharum*	*Saccharum angustifolium* Trin.		Doubtful	TG4					D'Hont et al. (2008).
			Saccharum asperum Steud.		Doubtful	TG4					
			Saccharum officinarum L.		Neophyte	TG1		GP1		X	
			Saccharum villosum Steud.	*Saccharum trinii* (Hack.) Renvoize	Doubtful	TG4					
Cassava	Euphorbiaceae	*Manihot*	*Manihot anomala* Pohl subsp. *pubescens* D.J.Rogers et Appan		Native	TG4	Section *Sinuatae*	?			Rogers and Appan (1973), Nassar et al. (2008).
			Manihot brachyloba Müll. Arg.		Native	TG4	Section *Peruvianae*				
			Manihot carthagenensis (Jacq.) Müll. Arg.		Native	TG4	Section *Carthaginenses*	?			
			Manihot esculenta Crantz		Native	TG1	Section *Manihot*	GP1	X	X	
			Manihot filamentosa Pittier		Endemic	TG4	Section *Carthaginenses*	?			

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Manihot surinamensis D.J. Rogers et Appan		Native	TG4	Section *Heterophyllae*				
			Manihot tristis Müll. Arg. subsp. *saxicola* D.J. Rogers et Appan		Native	TG4	Section *Heterophyllae*				
			Manihot tristis Müll. Arg. subsp. *tristis*		Native	TG4	Section *Heterophyllae*				
Plantain	Musaceae	*Musa*	*Musa* × *paradisiaca* L.		Neophyte	TG1				X	
Banana	Musaceae	*Musa*	*Musa* × *paradisiaca* L.		Neophyte	TG1				X	
Potato	Solanaceae	*Solanum*	*Solanum colombianum* Dunal		Native	TG2	SubSection *Potatoe*	Clade Potato	X		Hawkes (1990), Spooner et al. (1995), Spooner and Hijmans (2001), Huamán and Spooner (2002), Bohs (2005), Weese and Bohs (2007)
			Solanum curtilobum Juz. et Bukasov		Doubtful	TG2	SubSection *Potatoe*	Clade Potato	X		
			Solanum flahaultii Bitter	*Solanum paucijugum* Bitter	Doubtful	TG2	SubSection *Potatoe*	Clade Potato			
			Solanum juglandifolium Humb. et Bonpl. ex Dunal		Native	TG2	SubSection *Estolonifera*	Clade Potato			
			Solanum otites Dunal	*Solanum colombianum* Dunal	Native	TG2	SubSection *Potatoe*	Clade Potato	X		
			Solanum paramoense Bitter ex Pittier	*Solanum tuberosum* L. subsp. *andigena* (Juz. et Bukasov) Hawkes	Native	TG2	SubSection *Potatoe*	Clade Potato			
			Solanum subpanduratum Ochoa	*Solanum colombianum* Dunal	Native	TG2	SubSection *Potatoe*	Clade Potato	X		
			Solanum tuberosum L.		Native	TG1	SubSection *Potatoe*, series *Tuberosa*.	Clade Potato	X	X	

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Solanum tuberosum L. subsp. *andigena* (Juz. et Bukasov) Hawkes		Native	TG1	SubSection *Potatoe*, series *Tuberosa*	Clade Potato	X	X	
			Solanum woodsonii Correll	*Solanum colombianum* Dunal	Native	TG2	SubSection *Potatoe*	Clade Potato			
Eggplant	Solanaceae	*Solanum*	*Solanum melongena* L.		Neophyte	TG1					
Pineapple	Bromeliaceae	*Ananas*	*Ananas comosus* (L.) Merr. var. *comosus*		Archaeophyte	TG1		GP1	X	X	Leal and Coppens d'Eeckenbrugge (1996), Duval et al. (2001, 2003), Ruas et al. (2001).
			Ananas lucidus Mill.		Archaeophyte	TG1		GP1			
			Ananas nanus (L.B.Sm.) L.B.Sm.		Doubtful	TG1				X	
			Ananas parguazensis Camargo et L.B.Sm.		Native	TG1		GP2		X	
Onion	Alliaceae	*Allium*	*Allium cepa* L.		Neophyte	TG1				X	
Coffee	Rubiaceae	*Coffea*	*Coffea arabica* L.		Naturalized	TG1				X	
			Coffea canephora Pierre ex A.Froehner		Doubtful	TG1				X	
			Coffea liberica W.Bull ex Hiern		Naturalized	TG1				X	
Sorghum	Poaceae	*Sorghum*	*Sorghum arundinaceum* (Desv.) Stapf		Neophyte	TG1	*S. bicolor* subsp. *arundinaceum*				De Wet (1978).
			Sorghum bicolor (L.) Moench		Neophyte	TG1	*S. bicolor* subsp. *bicolor*	GP1	X	X	
			Sorghum halepense (L.) Pers.		Neophyte	TG2	Section *Sorghum*				
			Sorghum × *drummondii* (Nees ex Steud.) Millsp. et Chase		Neophyte	TG1	*S. bicolor* subsp. *drummondii*				
Tomato	Solanaceae	*Lycopersicon*	*Lycopersicon esculentum* Mill.		Doubtful	TG1			X	X	

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Lycopersicon esculentum Mill. var. *cerasiforme* (Dunal) A. Gray		Native	TG1			X	X	
Melon	Cucurbitaceae	*Cucumis*	*Cucumis anguria* L.		Naturalized	TG3	Section *Aculeatosi*	GP3			Deakin et al. (1971), Kho et al. (1980)
			Cucumis dipsaceus Ehrenb. ex Spach		Doubtful	TG3	Section *Aculeatosi*	GP3			
			Cucumis melo L.		Naturalized	TG1	Section *Cucumis*	GP1			
			Cucumis metuliferus Naudin		Naturalized	TG3	Section *Metuliferi*	GP3			
Cucumber	Cucurbitaceae	*Cucumis*	*Cucumis sativus* L.		Naturalized	TG1	Section *Cucumis*	GP2			
Peppers	Solanaceae	*Capsicum*	*Capsicum annuum* L.		Doubtful	TG1			X	X	Moscone et al. (2006), Walsh and Hoot (2001), Naci and Pickersgill (2004).
			Capsicum annuum L. var. *aviculare* (Dierb.) D'Arcy et Eshbaugh		Doubtful	TG1	*C. annuum* complex	GP1			
			Capsicum annuum L. var. *glabriusculum* (Dunal) Heiser et Pickersgill		Doubtful	TG1	*C. annuum* complex	GP1			
			Capsicum chinense Jacq.	*Capsicum annuum* L. var. *annuum*	Doubtful	?	*C. annuum* complex	GP2	X		
			Capsicum cumanense Fingerh.		Native	?	?	?			
			Capsicum frutescens L.		Native	?	*C. annuum* complex	GP2	X		
			Capsicum microcarpum Cav.	*Capsicum baccatum* L. var. *baccatum*	Native	?	*C. baccatum* complex	GP2	X		
			Capsicum pendulum Willd.	*Capsicum baccatum* L var. *pendulum* (Willd.) Eshbaugh	Native	?	*C. baccatum* complex	GP2	X		
			Capsicum pubescens Ruiz et Pav.		Doubtful	?	*C. pubescens* complex	GP2			

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Capsicum rhomboideum (Humb., Bonpl. et Kunth) Kuntze		Native	?	?	GP3			
Carrot	Apiaceae	*Daucus*	*Daucus carota* L.		Neophyte	TG1	Section *Daucus*				Sáenz-Laín (1981).
			Daucus montanus Humb. et Bonpl. ex Schult.		Native	TG4	Section *Anisactis*				
Coconut	Arecaceae	*Cocos*	*Cocos nucifera* L.		Naturalized	TG1				X	
Watermelon	Cucurbitaceae	*Citrullus*	*Citrullus lanatus* (Thunb.) Matsum. et Nakai		Naturalized	TG1		GP1			
Lime	Rutaceae	*Citrus*	*Citrus aurantiifolia* (Christm.) Swingle		Neophyte	TG1					
Lemon	Rutaceae	*Citrus*	*Citrus limon* (L.) Osbeck		Neophyte	TG1					
Mandarin	Rutaceae	*Citrus*	*Citrus reticulata* Blanco		Neophyte	TG1					
Orange	Rutaceae	*Citrus*	*Citrus sinensis* Osbeck		Neophyte	TG1				X	
Papaya	Caricaceae	*Carica*	*Carica papaya* L.		Naturalized	TG1					
Tobacco	Solanaceae	*Nicotiana*	*Nicotiana glauca* Graham		Native	TG4	Section *Noctiflorae*	GP3	X		Knapp et al. (2004), Trojak-Goluch and Berbeć (2003).
			Nicotiana tabacum L.		Archaeophyte	TG1	Section *Nicotiana*	GP1	X		
Yam	Dioscoreaceae	*Dioscorea*	*Dioscorea abysmophila* Maguire et Steyerm.		Endemic	?	?				Knuth (1924).
			Dioscorea alata L.		Neophyte	TG1	Section *Enantiophyllum*				
			Dioscorea amazonum Mart. ex Griseb.		Native	TG3	Section *Sarcantha*				
			Dioscorea atrescens R.Knuth		Endemic	TG3	Section *Strutantha*				
			Dioscorea bolivarensis Steyerm.		Endemic	TG3	Section *Sarcantha*				
			Dioscorea cayenensis Lam.		Neophyte	TG2	Section *Enantiophyllum*				
			Dioscorea crateriflora R.Knuth		Native	TG3	Section *Macrothyrsa*				

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Dioscorea crotalariifolia Uline		Native	TG3	Section *Apodostemon*				
			Dioscorea cuspidata Humb. et Bonpl. ex Willd.		Native	TG3	Section *Apodostemon*				
			Dioscorea decorticans C.Presl		Native	TG3	Section *Strutantha*				
			Dioscorea discolor Hort.Berol. ex Kunth		Native	TG3	Section *Lasiogyne*				
			Dioscorea holmioidea Maury		Endemic	?	?				
			Dioscorea laxiflora Mart. ex Griseb.		Native	TG3	Section *Cryptantha*				
			Dioscorea meridensis Kunth		Native	TG3	Section *Lychnostemon*				
			Dioscorea polygonoides Humb. et Bonpl. ex Willd.		Native	TG3	Section *Lychnostemon*				
			Dioscorea sororopana Steyerm.		Endemic	TG3	Section *Hemidematostemon*				
			Dioscorea trichanthera Gleason		Native	TG3	Section *Epistemon*				
			Dioscorea trifida L.f.		Native	TG1	Section *Macrogynodium*				
Tannia	Araceae	*Xanthosoma*	*Xanthosoma akkermansii* (G.S.Bunting) Croat		Endemic	?					Engler (1920).
			Xanthosoma aristeguietae (G.S.Bunting) Madison		Native	?					
			Xanthosoma bayo G.S.Bunting		Endemic	?					
			Xanthosoma bolivaranum G.S.Bunting		Endemic	?					
			Xanthosoma caulotuberculatum G.S.Bunting		Endemic	?					

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Xanthosoma conspurcatum Schott		Native	TG4	Section *Acontias*				
			Xanthosoma contractum G.S.Bunting		Endemic	?					
			Xanthosoma exiguum G.S.Bunting		Endemic	?					
			Xanthosoma helleborifolium Schott		Native	TG4	Section *Acontias*				
			Xanthosoma longilobum G.S.Bunting		Native	?					
			Xanthosoma mafaffoides G.S.Bunting		Endemic	?					
			Xanthosoma maroae G.S.Bunting		Endemic	?					
			Xanthosoma mexicanum Liebm.		Native	TG2	Section *Euxanthosoma*				
			Xanthosoma nitidum G.S.Bunting		Endemic	?					
			Xanthosoma orinocense G.S.Bunting		Endemic	?					
			Xanthosoma pariense G.S.Bunting		Endemic	?					
			Xanthosoma peltatum G.S.Bunting		Endemic	?					
			Xanthosoma sagittifolium (L.) Schott		Native	TG1	Section *Euxanthosoma*				
			Xanthosoma saguasense G.S.Bunting		Native	?					
			Xanthosoma striatipes (Kunth) Madison		Native	?					
			Xanthosoma trilobum G.S.Bunting		Endemic	?					
			Xanthosoma undipes K.Koch		Native	TG2	Section *Euxanthosoma*				

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
Avocado	Lauraceae	*Persea*	*Persea americana* Mill.		Naturalized	TG1	Subgenus *Persea*	GP1		X	Kopp (1966), Bergh and Ellstrand (1986).
			Persea areolatocostae (C.K.Allen) van der Werff		Endemic	TG4	Subgenus *Eriodaphne*	GP3			
			Persea bernardii L.E.Kopp		Native	TG4		GP3			
			Persea caerulea (Ruiz et Pav.) Mez		Native	TG4		GP3			
			Persea croatii van der Werff		Endemic	TG4		GP3			
			Persea croizatii van der Werff		Native	TG4		GP3			
			Persea cuneata Meisn.		Native	TG4		GP3			
			Persea fastigiata L.E.Kopp var. *fastigiata*		Endemic	TG4		GP3			
			Persea fastigiata var.*sericea* L.E.Kopp		Native	TG4		GP3			
			Persea fendleri van der Werff		Native	TG4		GP3			
			Persea ferruginea Kunth		Native	TG4		GP3			
			Persea fluviatilis van der Werff		Endemic	TG4		GP3			
			Persea grandiflora L.E.Kopp		Native	TG4		GP3			
			Persea jenmanii Mez		Native	TG4		GP3			
			Persea maguirei L.E.Kopp		Endemic	TG4		GP3			
			Persea meridensis L.E.Kopp		Native	TG4		GP3			
			Persea mutisii Kunth		Native	TG4		GP3			
			Persea perseiphylla (C.K.Allen) van der Werff		Native	TG4		GP3			
			Persea pseudofasciculata L.E.Kopp		Native	TG4		GP3			

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Persea rigens C.K.Allen		Native	TG4		GP3			
			Persea subcordata Ruiz et Pav.		Native	TG4		GP3			
Garlic	Alliaceae	*Allium*	*Allium sativum* L.		Neophyte	TG1					
Beans	Fabaceae	*Phaseolus*	*Phaseolus aborigineus* Burkart	*Phaseolus vulgaris* L. var. *aborigineus* (Burkart) Baudet	Native	TG1	Section *Phaseoli*	GP1	X		Freytag and Debouck (2002), Debouck (1999), Delgado-Salinas et al. (1999, 2006).
			Phaseolus coccineus L.		Doubtful	TG4	Section *Coccinei*		X		
			Phaseolus dumosus Macfad.		Doubtful	TG2	Section *Phaseoli*		X		
			Phaseolus erythroloma Mart. ex Benth.	*Macroptilium erythroloma* Urb.	Native	TG5		GP3			
			Phaseolus lunatus L.		Native	TG4	Section *Paniculati*	GP3	X		
			Phaseolus pilosus Kunth	*Vigna lasiocarpa* (Mart. ex Benth.) Verdc.	Native	TG5		GP3			
			Phaseolus speciosus Kunth	*Vigna speciosa* (Kunth) Verdc.	Native	TG5		GP3			
			Phaseolus tuerckheimii Donn.Sm.		Native	TG4	Section *Brevilegumeni*	?			
			Phaseolus unilobatus Pittier		Native	?	?	?			
			Phaseolus vulgaris L.	*Phaseolus vulgaris* L. var. *vulgaris*	Naturalized	TG1	Section *Phaseoli*	GP1	X	X	
Mango	Anacardiaceae	*Mangifera*	*Mangifera indica* L.		Naturalized	TG1				X	
Guava	Myrtaceae	*Psidium*	*Psidium acutangulum* DC.		Native	?		?			
			Psidium appendiculatum Kiaersk.		Native	?		?			
			Psidium brownianum Mart. ex DC.		Native	?		?			

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Psidium cinereum Mart. ex DC.		Native	?		?			
			Psidium densicomum Mart. ex DC.		Native	?		?			
			Psidium friedrichsthalianum Nied.		Native	?		?			
			Psidium guajava L.		Naturalized	TG1				X	
			Psidium guineense Sw.		Native	?		?			
			Psidium laruotteanum Cambess.		Native	?		?			
			Psidium maribense Mart. ex DC.		Native	?		?			
			Psidium salutare (Kunth) O.Berg		Native	?		?			
			Psidium sartorianum (O.Berg) Nied.		Native	?		?			
			Psidium striatulum DC.		Native	?		?			
Cacao	Sterculiaceae	*Theobroma*	*Theobroma bicolor* Humb. et Bonpl.		Native	TG4	Section *Rhytidocarpus*	?			Cuatrecasas (1964), Rondón and Cumana (2005), Sousa et al. (2004).
			Theobroma cacao L. subsp. *cacao*		Native	TG1	Section *Theobroma*	GP1	X	X	
			Theobroma cacao L. subsp. *sphaerocarpum* (A. Chev.) Cuatrec.		Native	TG1	Section *Theobroma*	GP1			
			Theobroma grandiflorum (Willd. ex Spreng.) Schum.		Native	TG4	Section *Glossopetalum*	GP2		X	
			Theobroma microcarpum Mart.		Native	TG4	Section *Telmatocarpus*	GP2			
			Theobroma obovatum Klotzsch ex Bernoulli		Native	TG4	Section *Glossopetalum*	?			
			Theobroma speciosum Willd.		Native	TG4	Section *Oreanthes*	?			

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Theobroma subincanum Mart.		Native	TG4	Section *Glossopetalum*	?			
Sesame	Pedaliaceae	*Sesamum*	*Sesamum orientale* L.		Naturalized	TG1			X	X	
Grape	Vitaceae	*Vitis*	*Vitis tiliifolia* Humb. et Bonpl. ex Roem. et Schult.		Doubtful	TG3	Subgenus *Vitis*.	GP2			
			Vitis vinifera L.		Neophyte	TG1	Subgenus *Vitis*				
Cabbage	Brassicaceae	*Brassica*	*Brassica oleracea* L. var. *capitata* L.		Neophyte	TG1					
Cauliflower	Brassicaceae	*Brassica*	*Brassica oleracea* L. var. *botrytis* L.		Neophyte	TG1					
Lettuce	Asteraceae	*Lactuca*	*Lactuca sativa* L.		Neophyte	TG1					
Cotton	Malvaceae	*Gossypium*	*Gossypium barbadense* L.		Native	TG1			X	X	
			Gossypium hirsutum L.		Naturalized	TG1			X		
Strawberry	Rosaceae	*Fragaria*	*Fragaria vesca* L.	*Potentilla vesca* Scop.	Naturalized	TG1					
Peach	Rosaceae	*Prunus*	*Prunus accumulans* (Koehne) C.L.Li et G.Aymard		Native	TG4	Subgenus *Laurocerasus*	?			Li and Aymard (1997), Lersten and Horner (2000), Wen et al. (2008).
			Prunus amplifolia Pilg.		Native	TG4	Subgenus *Laurocerasus*	?			
			Prunus espinozana C.L.Li		Endemic	TG4	Subgenus *Laurocerasus*	?			
			Prunus integrifolia Walp.	*Prunus recurviflora* Koehne	Doubtful	?					
			Prunus lichoana G.Aymard		Native	TG4	Subgenus *Laurocerasus*	?			
			Prunus moritziana Koehne		Native	?	?				
			Prunus myrtifolia (L.) Urb.		Native	TG4	Subgenus *Laurocerasus*	?			
			Prunus persica (L.) Batsch		Neophyte	TG1					
			Prunus pleuradenia Griseb.		Native	?	?				

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Prunus salicifolia Kunth	Prunus serotina subsp. capuli (Cav.) McVaugh; Prunus capulli Cav.	Doubtful	TG4	Subgenus *Padus*	?			
			Prunus skutchii I.M.Johnst.		Native	?	?				
			Prunus urotaenia Koehne		Native	?	?				
			Prunus wurdackii C.L.Li		Endemic	TG4	Subgenus *Laurocerasus*				
Beet	Chenopodiaceae	*Beta*	*Beta vulgaris* L.		Neophyte	TG1					
Sweet Potato	Convolvulaceae	*Ipomoea*	*Ipomoea batatas* (L.) Lam.		Native	TG1	Section *Eriospermum*	GP1	X	X	Austin and Huáman (1996), Díaz et al. (1996), Huang et al. (2002), Rajapakse et al. (2004), Srisuwan et al. (2006).
			Ipomoea cordatotriloba Dennst.		Native	TG2	Section *Eriospermum*	GP3			
			Ipomoea longeramosa Choisy		Native	TG2	Section *Eriospermum*	?			
			Ipomoea ramosissima Choisy		Doubtful	TG2	Section *Eriospermum*	GP3			
			Ipomoea tiliacea (Willd.) Choisy		Native	TG2	Section *Eriospermum*	?	X		
			Ipomoea trifida G.Don		Native	TG2	Section *Eriospermum*	GP2	X		
Pigeonpea	Fabaceae	*Cajanus*	*Cajanus cajan* (L.) Millsp.		Neophyte	TG1			X	X	
Sisal	Agavaceae	*Agave*	*Agave cocui* Trel. var. *cocui*		Native	TG3	Subgenus *Agave*	?			Gentry (1982).
			Agave cocui Trel. var. *laguayrensis* Hummelinck		Native	TG3	Subgenus *Agave*	?			
			Agave sisalana Perrine ex Engelm.	*Agave rigida* Mill.	Introduced	TG1	Subgenus *Agave*	?			
			Agave vivipara L.		Native	TG3	Subgenus *Agave*	?			
Soya	Fabaceae	*Glycine*	*Glycine max* (L.) Merr.		Neophyte	TG1				X	

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
Peanut	Fabaceae	*Arachis*	*Arachis hypogaea* L.		Doubtful	TG1	Section *Arachis*	GP1	X	X	Krapovickas and Gregory (1994), Gimenes et al. (2002).
			Arachis pintoi Krapov. et W.C.Greg.		Native	TG4	Section *Caulorrhizae*	GP3			
			Arachis prostrata Benth.		Doubtful	?					
Sunflower	Asteraceae	*Helianthus*	*Helianthus annuus* L.		Neophyte	TG1				X	
Peas	Fabaceae	*Pisum*	*Pisum sativum* L.		Neophyte	TG1				X	
Wheat	Poaceae	*Triticum*	*Triticum aestivum* L.		Neophyte	TG1			X		
Arracacha	Apiaceae	*Arracacia*	*Arracacia pennellii* Constance	*Arracacia elata* H. Wolff	Native	?		?			
			Arracacia tillettii Constance et Affolter		Native	?		?			
			Arracacia vaginata J.M.Coult. et Rose		Native	?		?			
			Arracacia xanthorrhiza Bancr.		Doubtful	TG1		GP1		X	
Pumpkins, Squash	Cucurbitaceae	*Cucurbita*	*Cucurbita ficifolia* Bouché		Archaeophyte	TG1					
			Cucurbita maxima Duch. ex Lam.		Archaeophyte	TG1					
			Cucurbita moschata Duchesne		Archaeophyte	TG1			X		
			Cucurbita pepo L.		Archaeophyte	TG1					
Palm Oil	Arecaceae	*Elaeis*	*Elaeis guineensis* Jacq.		Neophyte	TG1					
Spinach	Chenopodiaceae	*Spinacia*	*Spinacia oleracea* L.		Neophyte	TG1					
Cowpea	Fabaceae	*Vigna*	*Vigna adenantha* (G.Mey.) Maréchal, Mascherpa et Stainier		Native	TG4	Subgenus *Sigmoidotropis*, Section *Leptospron*	?	X		Marechal et al. (1978), Sonnante et al. (1996).
			Vigna candida (Vell.) Maréchal, Mascherpa et Stainier		Native	TG4	Subgenus *Sigmoidotropis*, *Section Sigmoidotropis*	?			
			Vigna juruana (Harms) Verdc.		Native	TG4	Subgenus *Lasiospron*	?	X		

Table 4 continued

Crop	Family	Genus	Taxon	Synonymous	Status	Taxon group	Taxonomic classification	Gene pool	*ex situ* Conservation		References
									International	National	
			Vigna lasiocarpa (Benth.) Verdc.		Native	TG4	Subgenus *Lasiospron*	?	X		
			Vigna linearis (Kunth) Maréchal, Mascherpa et Stainier		Native	TG4	Subgenus *Sigmoidotropis*, Section *Caracallae*	?	X		
			Vigna longifolia (Benth.) Verdc.		Native	TG4	Subgenus *Lasiospron*	?			
			Vigna luteola (Jacq.) Benth.		Doubtful	TG3	Subgenus *Vigna*, Section *Vigna*	?			
			Vigna peduncularis Fawc. et Rendle		Native	TG4	Subgenus *Sigmoidotropis*, Section *Pedunculares*	?	X		
			Vigna unguiculata (L.) Walp.		Neophyte	TG1	Subgenus *Vigna*, Section *Catiang*	GP1	X	X	
			Vigna vexillata (L.) A.Rich.		Doubtful	TG4	Subgenus *Plectotropis*, Section *Plectrotropis*	GP3	X		

References

Alfaro Y, Segovia V (2000) Maices del sur de venezuela clasificados por taxonomia numerica. I. Caracteres de la planta. Agron Trop 50(3):413–433

Austin DF, Huáman Z (1996) A synopsis of *Ipomoea* (*Convolvulaceae*) in the Americas. Taxon 45:3–38

Bergh B, Ellstrand N (1986) Taxonomy of the Avocado. Calif Avocado Soc Yearb 70:135–146

Bohs L (2005) Major clades in *Solanum* based on ndhF sequence data. In Keating RC, Hollowell VC, Croat TB (eds) A festschrift for William G. D'Arcy: the legacy of a taxonomist. Monogr Syst Bot Missouri Bot Gard 104:27–49

Bunting GS (1975) Nuevas especies para la revisión de las Aráceas Venezolanas. Acta Bot Venez 10:263–335

Bunting GS (1979) Una sinopsis de las Aráceas de Venezuela. Rev Fac Agron (UCV) 10:139–290

Bunting GS (1986) New taxa of Venezuelan Araceae. Phytologia 60(5):293–344

Bunting GS (1988) New taxa of Venezuelan Araceae (II). Phytologia 64(6):459–486

Caddick L, Wilkin P, Rudall P, Hedderson T, Chase M (2002) Yams reclassified: a recircumscription of Dioscoreaceae and Dioscoreales. Taxon 51:103–114

Chacón J, Madriñán S, Debouck D, Rodriguez F, Tohme J (2008) Phylogenetic patterns in the genus *Manihot* (Euphorbiaceae) inferred from analyses of nuclear and chloroplast DNA regions. Mol Phylogenet Evol 49:260–267

Chen LJ, Lee DS, Song ZP, Suh HS, Lu BR (2004) Gene flow from cultivated rice (*Oryza sativa*) to its weedy and wild relatives. Ann Bot 93:67–73

Croat T, Lambert N (1986) The Araceae of Venezuela. Aroideana 9:1–225

Cuatrecasas J (1964) A taxonomic revision of the genus *Theobroma*. Contr US Natl Herb 35(6):379–607

D'Arcy WG (1972) Solanaceae studies II: typification of subdivisions of Solanum. Ann Mo Bot Gard 59:262–278

D'Arcy WG (1991) The Solanaceae since 1976, with a review of its biogeography. In: Hawkes JG, Lester RN, Nee M, Estrada N (eds) Solanaceae III: taxonomy, chemistry, evolution. Royal Botanic Gardens, Kew, pp 75–137

D'Hont A, Mendes-Souza G, Menossi M, Vincentz M, Van-Sluys MA, Glaszmann JC, Ulian E (2008) Sugarcane: a major source of sweetness, alcohol, and bio-energy. In: Moore PH, Ming R (eds) Genomics of tropical crop plants. Springer, New York, pp 483–513

De Wet JM (1978) Systematics and evolution of *Sorghum* Sect. *Sorghum* (Graminae). Am J Bot 65(4):477–484

Deakin J, Bohn G, Whitaker T (1971) Interspecific hybridization in cucumis. Econ Bot 25(2):195–211

Debouck D (1999) Diversity in *Phaseolus* species in relation to the common bean. In: Singh S (ed) Common bean improvement in the twenty-first century. Kluwer, Dordrecht, pp 25–52

Delgado M (2005) Estudio del grado y los efectos de la liberación y uso de Organismos Modificados Genéticamente, derivados y productos que los contengan, en la república bolivariana de Venezuela. Consultoría Proyecto Marco Nacional de Seguridad de la Biotecnología en Venezuela. Ministerio del Poder Popular para el Ambiente, UNEP, GEF, Caracas

Delgado-Salinas A, Turley T, Richman A, Lavin M (1999) Phylogenetic analysis of the cultivated and wild species of *Phaseolus* (Fabaceae). Syst Bot 24(3):438–460

Delgado-Salinas A, Bibler R, Lavin M (2006) Phylogeny of the genus *Phaseolus* (Leguminosae): a recent diversification in an ancient landscape. Syst Bot 31(4):779–791

Díaz J, Schmiediche P, Austin D (1996) Polygon of crossability between eleven species of *Ipomoea*: section *Batatas* (Convolvulaceae). Euphytica 88:189–200

Duval M, Noyer J, Perrier X, Coppens d'Eeckenbrugge G, Hamon P (2001) Molecular diversity in pineapple assessed by RFLP markers. Theor Appl Genet 102:83–90

Duval M, Buso G, Ferreira F, Noyer J, Coppens d′ Eeckenbrugge G, Hamon P, Ferreira M (2003) Relationships in *Ananas* and other related genera using chloroplast DNA restriction site variation. Genome 46:990–1004

Engler HGA (1920) Additamentum ad Araceas—Philodendroideas; Araceae—Colocasioideae. In: Engler H, Das Pflanzenreich IV. 23E. Biblioteca digital del Real Jardín Botánico de Madrid. http://bibdigital.rjb.csic.es/spa/index.php. Accessed Feb 2009

FAO (1996a) Informe sobre el Estado de los Recursos Fitogenéticos en el Mundo. FAO, Roma

FAO (1996b) Plan de acción mundial para la conservación y utilización sostenible de los recursos fitogenéticos para la alimentación y la agricultura y la Declaración de Leipzig. FAO, Roma

FAO (2001) Tratado Internacional sobre los Recursos Fitogenéticos para la Alimentación y la Agricultura. FAO, Roma

FAO (2005) FAOSTAT. http://faostat.fao.org. Accessed Sept 2008

Freytag G, Debouck D (2002) Taxonomy, distribution, and ecology of the genus *Phaseolus* (Leguminosae-Papilionoideae) in North America, Mexico and Central America. Sida Bot Misc 23:1–300

Ge S, Oliveira G, Schaal B, Gao LZ, Hong DY (1999) RAPD variation within and between natural populations of the wild rice *Oryza rufipogon* from China and Brazil. Heredity 82:638–644

Gentry H (1982) Agaves of continental North America. University of Arizona Press, Tucson

Gimenes M, Lopes C, Valls J (2002) Genetic relationships among *Arachis* species based on AFLP. Genet Mol Biol 25:349–353

Grant UJ, Hatheway WH, Timothy DH, Cassalett C, Roberts LM (1965) Razas de maíz en Venezuela. Instituto Colombiano Agropecuario, Boletín Técnico No 1. Editorial ABC, Bogotá, Colombia

Harlan J (1992) Crops and man, 2nd ed. American society of agronomy Inc., Crop Science Society of America, Inc., Madison, Wisconsin, USA

Harlan J, de Wet J (1971) Towards a rational classification of cultivated plants. Taxon 20:509–517

Hawkes JG (1990) The potato: evolution, biodiversity and genetic resources. Belhaven Press, Oxford

Hijmans R, Spooner D (2001) Geographic distribution of wild potato species. Am J Bot 88:2101–2112

Hokche O, Berry P, Huber O (2008) Nuevo Catálogo de la Flora Vascular de Venezuela. Fundación Instituto Botánico de

Venezuela Dr. Tobías Lasser, Universidad Central de Venezuela. Caracas, Venezuela
Huamán Z, Spooner DM (2002) Reclassification of landrace populations of cultivated potatoes (*Solanum* Sect. *Petota*). Am J Bot 89:947–965
Huang J, Corke H, Sun M (2002) Highly polymorphic AFLP markers as a complementary tool to ITS sequences in assessing genetic diversity and phylogenetic relationships of sweetpotato (*Ipomoea batatas* (L.) Lam.) and its wild relatives. Genet Resour Crop Evol 49:541–550
Huber O, Duno R, Riina R, Stauffer F, Pappaterra L, Jiménez A, Llamozas S, Orsini G (1998) Estado actual del conocimiento de la flora en Venezuela. Documentos Técnicos de la Estrategia Nacional de Diversidad Biológica No 1. FIBV, MARNR, ENDIBIO, Caracas
IPNI (2011). The international plant names index. http://www.ipni.org. Accessed May 2011
Jena KK, Kochert G (1991) Restriction fragment length polymorphism analysis of CCDD genome species of the genus *Oryza* L. Plant Mol Biol 16(5):831–839
Juliano A, Naredo ME, Jackson MT (1998) Taxonomic status of *Oryza glumaepatula* Steud. I. Comparative morphological studies of New World diploids and Asian genome species. Genet Resour Crop Evol 45:197–203
Kho Y, Den Nijs A, Franken J (1980) Interspecific hybridization in *Cucumis* L. II. The crossability of species, an investigation of in vivo pollen tube growth and seed set. Euphytica 29:661–672
Khush G (1997) Origin, dispersal, cultivation and variation of rice. Plant Mol Biol 35:25–34
Knapp S, Chase M, Clarkson J (2004) Nomenclatural changes and a new sectional classification in *Nicotiana* (Solanaceae). Taxon 53(1):73–82
Knudsen H (2000) Directorio de colecciones de Germoplasma de América Latina y el Caribe. IPGRI, Rome
Knuth R (1924) Dioscoreaceae. In: Engler A (ed) Das Pflanzenreich, IV. 43. Biblioteca digital del Real Jardín Botánico de Madrid. http://bibdigital.rjb.csic.es/. Accessed Jan 2009
Kopp L (1966) A taxonomic revision of the genus Persea in the western hemisphere (Persea—Lauraceae). Mem NY Bot Gard 14(1):1–120
Krapovickas A, Gregory W (1994) Taxonomía del género *Arachis* (Leguminosae). Bonplandia 8:1–186
Leal F, Coppens d′Eeckenbrugge G (1996) Pineapple. In: Janick J, Moore JN (eds) Fruit breeding: tree and tropical fruits, vol 1. John Wiley and Sons Inc, New York, pp 515–556
Lersten NR, Horner N (2000) Calcium oxalate crystal types and trends in their distribution patterns in leaves of *Prunus* (Rosaceae: Prunoideae). Plant Syst Evol 224:83–96
Ley de Diversidad Biológica (2000) Gaceta Oficial 5468E (Extraordinaria). República Bolivariana de Venezuela. Caracas, Venezuela
Li C, Aymard G (1997) A new species and a new combination in *Prunus* subgenus *Lauracerasus* (Rosaceae) from the Venezuelan Guayana. BioLlania 6:449–454
Llamozas S, Duno R, Meir W, Riina R, Stauffer F, Aymard G, Huber O, Ortiz R (2003) Libro rojo de la flora Venezolana. PROVITA, Fundación Polar, Fundación Instituto Botánico de Venezuela. Caracas
Luteyn J (1999) Páramos: a checklist of plant diversity, geographical distribution and botanical literature. The New York Botanical Garden, New York
Mabberley DJ (2008) The plant—book: a portable dictionary of the vascular plants. Cambridge University Press, UK
Madison M (1981) Notes on *Caladium* (Araceae) and its allies. Selbyana 5:342–377
Magos J (2008) Conservation of wild plant genetic resources in Portugal. PhD Thesis, University of Birmingham, UK
Magos J, Maxted N, Ford-Lloyd BV, Martins-Loução MA (2008) National inventories of crop wild relatives and wild harvested plants: case-study for Portugal. Genet Resour Crop Evol 55(6):779–796
Marechal R, Mascherpa JM, Stainier F (1978) Etude taxonomique d′un groupe complexe d′espèces des genres *Phaseolus* et *Vigna* (Papilionaceae) sur la base de dones morphologiques et polliniques, traitées par l′analyse informatique. Boissiera vol 28
Maxted N, Ford-Lloyd BV, Hawkes JG (1997) Plant genetic conservation: the in situ approach. Chapman and Hall, London
Maxted N, Ford-Lloyd BV, Jury S, Kell S, Scholten M (2006) Towards a definition of a crop wild relative. Biodivers Conserv 15(8):2673–2685
Maxted N, Scholten M, Codd R, Ford-Lloyd B (2007) Creation and use of a national inventory of crop wild relatives. Biol Conserv 140(1–2):142–159
Mcleod M, Guttman S, Hardy W (1982) Early evolution of chili peppers *(Capsicum)*. Econ Bot 36(4):361–368
Mignouna HD, Abang MM, Asiedu R (2007) Yams. In: Kole C (ed) Genoma mapping and molecular breeding in plants: pulses, sugar and tuber crops, vol 3. Springer, Berlin, pp 271–296
Moscone E, Scaldaferro M, Grabiele M, Cecchini N, Sanchez Y, Jarret R, Daviña J, Ducasse D, Barboza G, Ehrendorfer F (2006) The evolution of chili peppers (*Capsicum*—Solanaceae): a cytogenetic perspective. In: Spooner DM et al. (eds) VI International Solanaceae Conference. Acta Hort 745:137–169
Naci A, Pickersgill B (2004) Unilateral Incompatibility in *Capsicum* (Solanaceae): Occurrence and taxonomic distribution. Ann Bot 94:289–295
Naredo MEB, Juliano AB, Lu BR, Jackson MT (1998) Taxonomic status of *Oryza glumaepatula* Steud. II. hybridization between New World diploids and AA genome species from Asia and Australia. Genet Resour Crop Evol 45:205–214
Nassar N, Hashimoto D, Fernandes S (2008) Wild *Manihot* species: botanical aspects, geographic distribution and economic value. Genet Mol Res 7(1):16–28
Nee M (1999) Synopsis of *Solanum* in the new world. In: Nee M, Symon DE, Lester RN, Jessop JP (eds) Solanaceae IV. Royal Botanic Gardens, Kew, pp 285–333
Pittier H (1944) Leguminosas de Venezuela. Papilionáceas. Boletín Técnico del Ministerio de Agricultura 5:113–122
Rajapakse S, Nilmalgoda S, Molnar M, Ballard R, Austin D, Bohac J (2004) Phylogenetic relationships of the sweetpotato in *Ipomoea* series *Batatas* (Convolvulaceae) based on nuclear b-amylase gene sequences. Mol Phylogenet Evol 30:623–632
Rogers D, Appan S (1973) *Manihot* and *Manihotoides* (Euphorbiaceae): a computer assisted study. Flora Neotropica, monograph no 13. Hafner Press, New York

Rondón J, Cumana L (2005) Revisión taxonómica del género *Theobroma* (Sterculiaceae) en Venezuela. Acta Bot Venez 28(1):113–134

Ruas CF, Ruas PM, Cabral JR (2001) Assessment of genetic relatedness of the genera *Ananas* and *Pseudananas* confirmed by RAPD markers. Euphytica 119:245–252

Sáenz-Laín C (1981) Research on *Daucus* L. *(Umbelliferae).* An Jard Bot Madr 37(2):481–533

Sonnante G, Piergiovanni A, Ng Q, Perrino P (1996) Relationships of *Vigna unguiculata* (L.) Walp., *V. vexillata* (L.) A. Rich and species of section *Vigna* based on isozyme variation. Genet Resour Crop Evol 43:157–165

Sousa C, Venturieri G, Figueira A (2004) Description of Amazonian *Theobroma* L. collections, species identification, and characterization of interspecific hybrids. Acta Bot Bras 18(2):333–341

Spooner DM, Hijmans RJ (2001) Potato systematics and germplasm collecting, 1989–2000. Am J Potato Res 78: 237–268

Spooner DM, Castillo R, López L, Pineda R, León R, Vargas A, García ML, Bamberg J (1995) Colombia and Venezuela 1992 wild potato (*Solanum* sect. *Petota*) germplasm collecting expedition: taxonomy and new germplasm resources. Euphytica 81:45–56

Srisuwan S, Sihachakr D, Siljak-Yakovlev S (2006) The origin and evolution of sweet potato (*Ipomoea batatas* Lam.) and its wild relatives through the cytogenetic approaches. Plant Sci 171:424–433

Subudhi P, Sasaki T, Khush G (2006) Rice. In: Kole C (ed) Genome mapping and molecular breeding in plants: cereals and millets, vol 1. Springer, Berlin

Trojak-Goluch A, Berbeć A (2003) Cytological investigations of the interspecific hybrids of *Nicotiana tabacum* L. × *N. glauca* Grah. J Appl Genet 44(1):45–54

Vaughan DA, Tomooka N (1999) Wild rice in Venezuela. Rice genetics newsletters. http://www.gramene.org/newsletters/rice_genetics/. Accessed Oct 2009

Vaughan DA, Morishima H, Kadowaki K (2003) Diversity in the *Oryza* genus. Curr Opin Plant Biol 6:139–146

Walsh B, Hoot S (2001) Phylogenetic relationships of *Capsicum* (*Solanaceae*) using DNA sequences from two noncoding regions: the chloroplast *atpB-rbcL* spacer region and nuclear waxy *introns*. Int J Plant Sci 162(6):1409–1418

Weese TL, Bohs L (2007) A three-gene phylogeny of the genus *Solanum* (*Solanaceae*). Syst Bot 32(2):445–463

Wen J, Berggren S, Lee CH, Ickert-Bond S, Yi TS, Yoo KO, Xie L, Shaw J, Potter D (2008) Phylogenetic inferences in *Prunus* (Rosaceae) using chloroplast *ndh*F and nuclear ribosomal ITS sequences. J Syst Evol 46(3):322–332

Wilkin P, Schols P, Chase M, Chayamarit K, Furness C, Huysmans S, Rakotonasolo F, Smets E, Thapyai C (2005) A plastid gene phylogeny of the Yam Genus, *Dioscorea*: Roots, Fruits and Madagascar. Syst Bot 30(4):736–749